SECTION II.—GENERAL METEOROLOGY.

METEOROLOGY OF THE MOON.[1]

By Prof. WILLIAM H. PICKERING.

[Dated: Harvard Astronomical Station, Mandeville, Jamaica, February 4, 1916.]

In the days of Sir William Herschel it was believed that the moon was a living planet, with active volcanoes, and even possibly intelligent life upon its surface. In the nineteenth century astronomers changed their views, and following them the public. The change was gradual, but toward the end of the century many went so far even as to say that no alterations of surface of any kind had ever been detected upon the moon and that it was a dead, changeless, and burned-out cinder. And this was said and written in spite of the expressed opinion of all of the world's greatest selenographers to the contrary—Schroeter, Maedler, Schmidt, Webb, Neison, Birt, Elger, Klein, and others. That is, the opinions of those who had made a life-study of the moon were all disregarded as of no value, in favor of the views of some modern popular astronomers who had never given even a single month's study to our satellite.

Of late years, however, more attention has been paid to the moon. Instead of its being totally neglected by astronomers, powerful telescopes situated in favorable climates have been turned on it, with the result that the pendulum has already begun to swing the other way. Thus M. Jassy Desloges,[2] using a 20-inch telescope located in Algeria, has confirmed certain changes noted by the writer in the craters Linné, Plato, and Messier, has detected certain others which have since arisen, and has made other observations showing changes in Dawes and Alpetragius. The director of the lunar section of the British Astronomical Association,[3] in a recent paper, says: "It is now well established that periodic changes do occur in each lunation in connection with many objects on the moon's surface."

In a discussion of lunar changes, and particularly of lunar meteorology, it is necessary first to state a few astronomical facts, and explain a few astronomical terms. Thus the earth and the moon both revolve about the sun in nearly the same orbit, but are continually crossing one another's paths, and mutually disturbing one another as they go, both orbits being always concave toward the sun. The diameters are not unlike, being in the ratio of 3.7 to 1. The earth-moon system is therefore, strictly speaking, simply a double planet. It is not at all similar to the case of the other satellite systems, where each satellite revolves primarily about a comparatively very large planet, and only secondarily and in consequence follows that body about the sun. In one respect our twin world differs very markedly from the earth—its equator is nearly parallel to its solar orbit. The inclination is only 1.5° in place of 23.5° as with us, and consequently there are no marked polar caps and no seasons in the sense that we find them on the earth. On the other hand the lunar day with regard to the sun is 29.5 of our days in length, instead of 24 hours.

For practical purposes, however, there are seasons, much as we have them at the terrestrial poles, and we may consider that for each lunar crater spring begins at lunar sunrise upon it, and lasts nearly 7.5 days, till the sun crosses its meridian which is its summer solstice. When the sun sets upon it 7.5 days later, we have its autumnal equinox. The winter solstice occurs when the sun is on the opposite side of the moon, 14.75 days after its midsummer. At the same moment that it is spring for one crater it may be summer for another, autumn for a third, and winter for a fourth, depending on their longitudes. The main difference between the conditions on the moon and at our poles is that the 6 months of daylight on the earth is reduced to 15 days upon the moon. The lunar days, however, are much hotter, and the lunar nights far colder than with us.

Astronomers measure the progress of the lunar day, which may thus also be considered to coincide with its year, in degrees of colongitude, as we measure the progress of the terrestrial day in hours of time. Colongitude 0° occurs when it is sunrise on the central meridian of the moon, that is in general at the first quarter. When it is colongitude 90° the moon is full, at colongitude 180° it is the third quarter, and at colongitude 270° it is new moon. We say "in general" because the phases of the moon depend upon the position of the earth, and occur therefore at somewhat irregular intervals, while the colongitudes depend on the position of the sun as seen from the moon, and are much more regular, corresponding to "Greenwich apparent time" on the earth.

Since longitudes on the moon are also counted from the central meridian, it follows that the common colongitude of the whole moon is always numerically equal to the longitude of those portions of its surface where the sun is rising, but this we need not stop to discuss further than to mention the fact.

Turning now for a moment to the planet Mars, which the moon resembles more closely than it does the earth. the fundamental fact on which is based the study of its meteorology is the melting of its polar caps. The moon has no well-defined polar caps, although its northern and southern limbs are appreciably brighter than either of its equatorial ones. There are, however, scattered over the whole of its surface, but in particular near its poles, numerous minute white spots more or less sharply defined and which we believe are due to snow or frost, and it is to some of these that we shall now direct our attention.

The object with which we will begin our studies is the well-known mountain Pico. This mountain is situated in longitude 9°, latitude +45°. Its vernal equinox therefore occurs at colongitude 9°, its summer solstice at colongitude 99° or just after full moon, and its autumnal equinox at 189°. Its altitude is 8000 feet or 2500 meters, and its length east and west 10″, 11 miles or 18 kilometers. No craters whatever have been detected upon it, but if any existed that were less than 0.1″ (500 feet or 150 meters) in diameter they would probably have escaped notice. It is not strictly a mountain in the geological sense of the word, but rather a spiracle or pinnacle, such as occur in some of our volcanic regions (Mem. Amer. Acad., **13**, Plates 19 and 20). Perhaps the best idea of

[1] Reprinted, with alterations by the author, from "Popular Astronomy," Williams Bay, Wis., March, 1915, v. 23, No. 3. The illustrations, figures 1 to 8, inclusive, have been reengraved from the original drawings.—C. A. jr.

[2] Desloges, Jassy: Observations des surfaces planétaires, 2, 201, 215.

[3] Brit. astron. ass'n., 1915, **26**, 28.

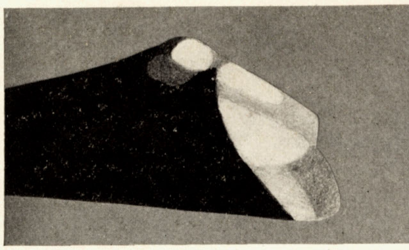

Fig. 1
Jan. 24, 1915
19°.6, ×330, S. *9*

Fig. 2
Jan. 25, 1915
32°.9, ×430, S. *12*

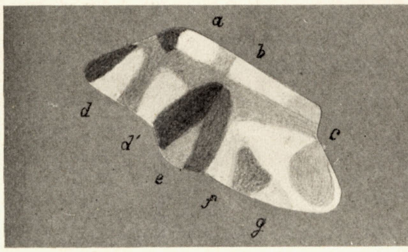

Fig. 3
Jan. 27, 1915
55°.9, ×430, S. *10*

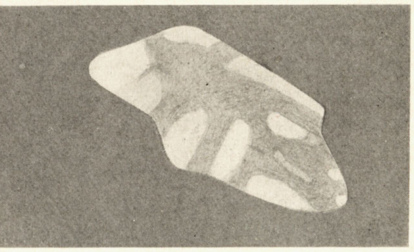

Fig. 4
Jan. 29, 1915
81°.8, ×430, S. *11*

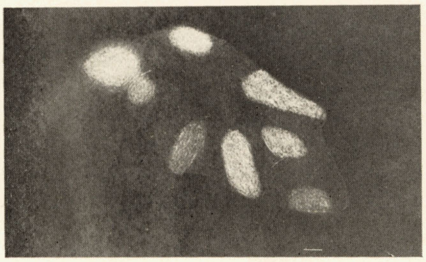

Fig. 9
Sept. 24, 1912
78°.8, ×330, S. *10*

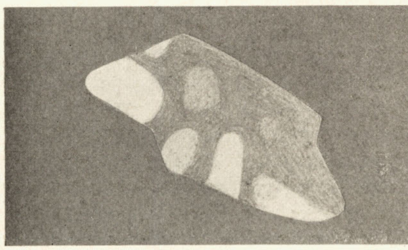

Fig. 5
Sept. 28, 1912
126°.7, ×330, S. *10*

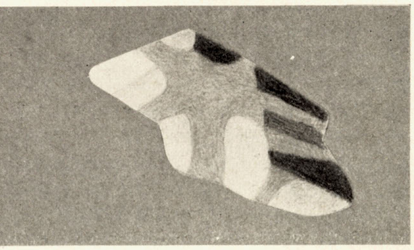

Fig. 6
Jan. 31, 1915
132°.2, ×430, S. *10*

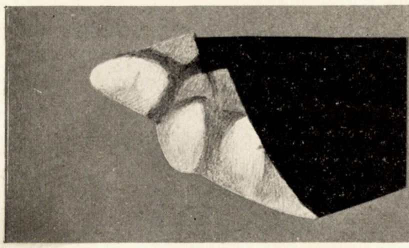

Fig. 7
Sept. 3, 1912
183°.6, ×330, S. *12*

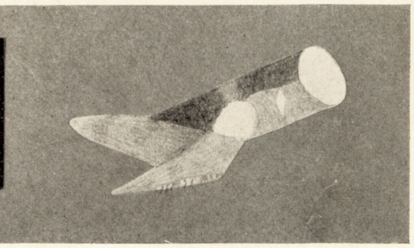

Fig. 8
Sept. 23, 1912
64°.4, ×330, S. *8*

its appearance as compared with terrestrial mountains may be obtained from figure 7. The figures on this plate are all oriented with north at the top. This is unusual, but is better adapted to the illustration of the present paper than the usual orientation would be.

It is perhaps unnecessary to state that every line and shading shown in the drawing actually exists on the moon. It has not been touched up in any way to give it a resemblance to a terrestrial peak, but the mountain is represented exactly as it appears as seen through the telescope. Independent drawings made a little earlier and later in the lunation show practically every detail shown in the present sketch. It was drawn just as the sun was setting upon it, and consequently its western side is invisible. It must be remembered that on the moon the terms east and west are given the reverse meaning that they have on the earth and Mars. What we call east on the planets is called west on the moon, and vice versa.

Although this view gives the effect of having been sketched from but a slight elevation above the plain on which the mountain is situated, yet the angular elevation of the line of sight, as is shown by the latitude above given, is 45°. Pico is therefore not quite as steep as it appears in the sketch, the eastern slope lying at an angle of approximately 35°, and the western (shown in figure 1) of about 42°. It is also noticeable that the snow is found on the ridges, and not in the ravines, as in the case of our own large accumulations of ice. This is even more conspicuous in the case of Teneriffe shortly before the time of full moon, where the ridges and ravines are much more marked than they are on Pico.

As to the origin of the formation, it is pretty clearly a piece of the original lunar crust which was surrounded but not overwhelmed by the great fissure eruption causing the Mare Imbrium. The fact that the snow is found mainly upon the ridges leads us to believe that cracks exist along their crest lines. From these cracks water vapor escapes, and on account of the deficiency of the lunar atmosphere is immediately redeposited as snow. This peculiarity is shared by other lunar mountains as we have just seen.

In the accompanying plate the first seven drawings represent Pico. Under each is given the date, the colongitude, the magnification employed, and the quality of the seeing on a scale of 12. On this scale "12" is perfect for our 11-inch telescope, while "8" is better than we ever have in the north. Located upon the mountain are eight prominent white patches which we shall designate as snow. They have been lettered as indicated in figure 3. Although located in longitude 9°, yet so high does it rise above the surrounding plain, that the sun first touches its summit shortly before colongitude 7°. At 7.1° not only is spot *a* located upon the very summit of the mountain, dazzlingly brilliant; but the more elevated portions *b* and *c* can also be seen. By 9° *c* has rapidly increased in size, but *a* and *b* are practically unaltered.

At colongitude 19.6°, figure 1, *c* has about doubled its size, and other portions of the mountain are now visible, together with its long shadow, which is not shown in full on the plate, stretching away toward the east. Spot *a* is of brightness 10, and *b* and *c* 9, or a very little fainter.

By colongitude 32.9°, figure 2, nearly the whole of the southeastern side of the mountain has become visible, but none of the snow patches located upon it in some of the later figures have yet formed. Directly below the eastern summit, however, a crescent-shaped area has appeared which was described and painted as distinctly green, greener than the *mare,* which itself at this age of the moon is slightly greenish. Beneath the crescent a large area appears which is still in shadow, and close at hand to the west is another one, while spot *a* has increased in size, and the whole of it is now illuminated; spot *c* on the other hand has diminished, probably through melting. The next night at colongitude 44.0° much trouble was experienced from passing clouds, but it was clear that *a* was unchanged, while *c* had increased in size, appearing as in figure 1. This fluctuation in the size of *c* has been confirmed by later observations. The whole of the southeastern face was still dark. An observation made on September 21, 1912, at 40.7° records that there was no snow at all at that time on the eastern face of Pico.

In figure 3, colongitude 55.9°, the whole eastern face is resplendant with freshly formed snow, yet not quite so brilliant as at the higher levels, perhaps because on the lower and steeper slopes small projections of rock more frequently interrupt the bright surface. Spot *c* has greatly increased in size, *a* has diminished by melting away from the eastern end of the ridge, while new spots have formed at *d*, *d'*, *e*, *f*, and *g*. Spots *d*, *d'*, *e*, and the western ends of *b* and *c* were distinctly greenish, and this appearance frequently occurs when the formation of snow is very light, due perhaps to small scattered patches. The effect may be subjective, although it does not look as if it were. Spots *f* and *g* were the brightest of the southeastern patches, a supremacy which the southern one, *g*, soon loses under the influence of the direct summer sun.

The next night, 68.2°, spot *a* had returned to the eastern end of the ridge, increasing slightly in size at the same time; *b* and *c* had diminished, the latter notably; indeed *c* varies more in size and shape than any other spot on the mountain. This is quite natural since it lies on a wide comparatively level region, with a southern exposure. In fact it had broken into several smaller pieces which are shown in the drawing made on the following night. Changes were suspected between drawings made early and late in the evening. Spot *e* had increased in size but not in brightness. Spots *d* and *d'* had now united, but *d* was distinctly the brighter of the two.

An interesting phenomenon is exhibited at this colongitude, when spots *a* and *d* begin apparently to steam. In a few hours thick clouds of vapor are thrown off, especially from *d*, so that its outlines become very hazy, and quite different from its earlier and later appearance, and from the other spots about it. Its color becomes decidedly bluish, and the fog or mist in a thin transparent stream is swept off across the *mare* to the south, as indicated in figure 9. The action becomes less violent about colongitude 90° and by 95° has ceased altogether, as a usual thing, although it was observed on one occasion at the base of *d* as a very faint haze as late as 115°. All the spots have occasionally been recorded as slightly hazy at about this time, but none of the others are at all comparable in this respect to *d*. At colongitude 76.8° the ridges of Teneriffe have been recorded as steaming from end to end. In the meantime neighbouring bright spots were perfectly sharp and distinct. This steaming might be either a case of melting snow or of volcanic activity, the steam condensing into ice crystals and falling as snow. The writer rather favors the latter view, since the other spots do not exhibit it.

Knowing what to expect at this colongitude, *d* was carefully examined early in the evening at 68.8° and was recorded as "not notably hazy." At 70.0° it was recorded

"d and d' rather indistinct, d the most so, but not as hazy as they have been seen." At 70.1° "d is now clearly hazy." The next night at 81.9° "all spots are more or less hazy, but dd' especially so." Where the steam flows away at the base of the mountain across the *mare* it is extremely faint.

The following are all the other records that have been made pertaining to the haziness of d.

September 23, 1912. 64.8°. No steam from Piton or Pico *B*, but Pico sending a thin streak south from d.

February 18, 1913. 65.4°. The "snowstorm" has begun on a and d, but d is very faint, greenish, and quite separate from d'.

December 21, 1912. 69.3°. The snowstorm has begun. d, e, f, and g are all hazy and bluish, but d much the most so, while a, b, and c are very sharp.

March 20, 1913. 71.4°. Pico d and d' enveloped in cloud.

August 25, 1912. 72.0°. Pico is perhaps beginning to steam.

November 22, 1912. 74.4°. Pico. Snowstorm on the northeast peak (d) well developed, bluer than the other peaks. The northern peak (a) shows the same to a less marked degree. 74.6°. Snowstorm wonderfully well developed.

September 24, 1912. 78.5°. Pico d is very foggy as compared to b, c, e, f, and g. Spot a is a little foggy, but nothing like so markedly so as d. The contrast between d and f especially is very striking.

December 22, 1912. 81.8°. Pico. The snowstorm on d still continues, but it is not so hazy to-night.

August 26, 1912. 84.1°. As compared with last night, 72.0°, d has grown larger and more fuzzy.

March 21, 1913. 84.4°. Pico d is still a trifle brighter than f. It is a little more hazy.

January 21, 1913. 86.0°. Pico, storm at a, b, c, d, and d'.

September 25, 1912. 90.4°. All the spots except c, e, and f are as hazy as a; d no more so than the others.

December 23, 1912. 94.3°. Pico d is now much the brightest. The snowstorm is over.

January 22, 1913. 97.8°. Pico a and d have increased in size and are still a trifle hazy.

November 27, 1912. 99.5°. Pico d. Cannot be sure if the haziness has disappeared. 100.5°. Think the snowstorm still continues, but has diminished.

September 26, 1912. 103.3°. All the spots are sharp.

August 28, 1912. 109.5°. A very faint haze extending south from d.

November 25, 1912. 113.2°. The snowstorm has ceased.

September 27, 1912. 115.2°. The base of d and d' is perhaps a little hazy, but all the rest of the mountain seems clear, including Pico a.

September 28, 1912. 126.7°. All the bright areas on all the mountains seem to be sharp.

The "snowstorm" referred to in several of these extracts is a possible explanation of the phenomenon observed, since, as it progresses, d gradually becomes brighter than before and sometimes larger. At the same time d is clearly shown, with sharp borders, one day before the general haziness usually appears. Moreover, some of the other spots, notably f, are equally bright with d, and only on the rarest occasions appear hazy.

In figure 4, colong. 81.8°, the notable changes from the previous one are the coalescing of spots d and d', and the breaking up of c into small pieces. Spot e has broadened and grown brighter, gradually advancing toward the east. No marked change occurs for the next three days, save that the haze on the *mare* at the foot of d becomes more distinct. At the end of that time, at colongitude 115.1°, spots a, b, and c are found sometimes to have shifted their position angles so as to lie nearly northwest and southeast. Spot a does this by gradually working its way around the northern corner of the mountain. Spots b and c change more suddenly. On January 31, 1915, at colongitude 106.7°, spot b had disappeared.

In figure 5, 126.7°, an entirely new though faint spot, which we have called h, has formed midway between a and f. This drawing is the only one which has been secured of it. The previous night a drawing was made showing all the other eight areas, but nothing in the place of h. The following night c had disappeared and the brightness of all the other areas is recorded, but no mention is made of it. Moreover, neither the drawings and estimates of brightness made December 25, 1912, 118.7°, and December 26, 1912, 130.4°, nor figure 6, made January 31, 1915, 132.2°, show any trace of it, although it was looked for carefully on the latter night. It has been seen on one or two occasions during the past year.

An examination of figure 6, 132.2°, shows clearly the location of two ridges situated on the western flank of the mountain, whose shape explains in part the forms of spots b and c. By colongitude 147.9° the sun has set on the western slope, and in that drawing and at 159.3° the appearance is very similar to that at 183.6° when figure 7 was drawn. The chief difference is that in the earlier drawings the spots d, d', e, and f all reached down to the level of the *mare*, while in the later one at 183.6° d', e, and f have already begun to melt and disappear at their bases. This does not always happen, however, for on October 3, as late as 189.5°, d, d', and e are all shown as reaching down to the level of the *mare*, the terminator at this time passing through the base of the mountain.

As the result of observations made on 29 dates, extending over two years and a half, and lying between colongitudes 7.1° and 189.5°, we may summarize our results and state that spots a, b, and c first became visible at sunrise with full brilliancy 10, and that d, d', e, f, and g appear at 56° with brilliancies 6 to 8, some two days after the sun first reaches the eastern side of the mountain. At about 80° these latter points brighten, but with the exception of d never reach full brightness. Just before this d becomes very hazy for a couple of days and a less so. At 100° a, b, and c begin to fade and at 130° the two last disappear, the sun setting upon that part of the mountain about two days later. At 130° g begins to fade, but all the spots save b and c are visible until near sunset. Spot h appeared once for a short time at 127°. Spot c is the one which varies most in size and shape during the lunation and also from one lunation to another. Its variations are most marked between colongitudes 45° and 70°.

Other mountains in this immediate vicinity carry spots of variable size, and also present other features of interest. Just to the south of Pico, in longitude 9°, latitude +43°, lies the long elevated ridge Pico *B*, not to be confounded with the crater Pico B, located beyond the Teneriffe Mountains. "*B*" rises at the western end to a height of 5000 feet above the surrounding plain, and is about 10 miles in length. On account of its isolated position it is visible in nearly its entire length at colongitude 7.1°, the western end and middle peak being brilliant with snow. These spots are very persistent, and by 56.2° are more conspicuous than anything on Pico itself. The northeastern side of the ridge is now beginning to show, and by 69.8° is clearly seen. On July 23, 1912, 26.6°, it is recorded "the upper slopes of Pico and nearly the whole of *B* are as bright as the brightest summits of the Alps." This certainly was not the case on January 24 or 25, 1915, 19.8°, 33.6°, when the two spots were but little larger than indicated in figure 8. On September 23, 1912, 64.4° (fig. 8), a small but easily seen white spot, one mile from top to bottom by one quarter of a mile in width, lay upon the southern slope of the mountain halfway between the two larger spots. It was visible also September 24 and 25, 78.5°, 90.4°, but the next night, 103.3° had disappeared. This spot was also visible August 26, 1912, 84.3°, but the next night had vanished. It did not appear this year at all, but on January 28, 69.8°, a faint line of snow lay along the crest of the mountain connecting the two large spots, thus lying at right angles to that seen in 1912. The next night the line of snow had already begun to melt at both ends, thus severing its connection with the spots.

A curious feature which shows well on this mountain appears at or a little earlier than 69.8°. This is a row of almost contiguous bright dots which make their appearance along the eastern portion of the southern base (see fig. 8,) just where it rises from the plain. They are never very bright, seldom exceeding 7, but they gradually extend further toward the east. Two nights later another row extending the whole length of the northern base is also seen. Similar rows line both sides of Schroeter's Valley near Aristarchus, as also the rills of Hyginus and Ariadæus, although the last is rather faint. They look like columns of steam or cloud, and it is possible such may really be the case, as these are just the locations where hot springs occur in the case of the earth. If they are due to springs of water they need not necessarily be hot, since on account of the low atmospheric pressure, water would boil at the freezing point, 32°F., on the moon. Whatever their explanation, they form it is believed a hitherto undescribed feature of the lunar landscape.

On September 25, 1912, at 90.4°, Pico *B* was steaming vigorously at its eastern end, the steam drifting off across the *mare* toward the north. This is the only record we have of steam clouds from this mountain. On February 2, 1915, 132.4°, the western spot had vanished, while that at the middle was faint. September 29, 1912, at 139.9°, it too had gone. Somewhat earlier, spots had appeared on the north-eastern face, and one near the middle was quite conspicuous on August 31, 1912, at 148.1°. Nothing of the sort was seen February 3, 1915, at 146.6°. On September 1, 1912, at 166.2°, a second smaller spot appeared just west of the other. The southwestern slope of the mountain was still visible, but the next night was enveloped in shadow, and another small spot had appeared on the northeastern side. This was our latest observation of it.

While these observations are all easy enough here in Jamaica, it is undoubtedly true that many of the phenomena recorded would be difficult with the inferior atmospheric conditions existing in the north. It has, therefore, always been the writer's aim to find and describe the most conspicuous changes that he has been able to detect. A marked irregular change recently occurred in Eimmart, and has been described by him in Astronomische Nachrichten no. 4704, but there are regular changes constantly occurring within that crater, in some cases differing from one lunation to another, of about the same degree of visibility as those observed upon Pico.

With his 3-inch finder and a magnification of 180 he has been able to see clearly spot *d–d'* on Pico, and to suspect *f*, at about the time of full moon. With a somewhat larger aperture these and perhaps some of the others should be visible in the north, so that it should be possible to record the times of their appearance and disappearance. The same should be true of the two spots on Pico *B*.

Among the most difficult observations to confirm would probably be those relating to the so-called snowstorm on Pico *d*. Where the seeing is continually bad, all outlines are indistinct and therefore little difference would show even between *d* and *f*. Where, on the other hand, two or three diffraction rings are almost stationary around the brighter stars, with the full aperture of 11 inches and a magnification of 800, as occurs here with our best seeing (S. 12), it is plain that details on the moon present a sharpness of outline quite unknown in the north. That certain bright spots such as Linné are always hazy, is well known. The peculiarity of Pico *d* is that it is hazy only at specified seasons on the moon, when other neighboring and similar spots are sharp.

There are, however, other objects on the moon similar in their characteristics to *d*, which are much easier to observe. One of these is Sulpicius Gallus *B*, so designated on Goodacre's map, but not shown by Neison. The crater is located in longitude 351°, latitude +20°. On its eastern interior wall there is an intensely brilliant pear-shaped spot, very conspicuous just before full moon. It clearly changes its shape at different times, and is very hazy and indistinct between colongitudes 30° and 120°, although sharply defined earlier and later in the lunation. The duration of the indistinct period is thus much greater than on Pico *d*, and the change in appearance is so marked that the writer feels convinced it should be capable of detection in the north.

It has recently been found that the western end of the Straight Range presents changes that are fairly conspicuous. The sunlight first strikes it at colongitude 20°. It is then intensely brilliant, especially at its northern edge. By 44° it is rather less bright. By 70° all the snow has gone except at the north and the bare rock, of brightness 6, looks red in contrast with the greenish *mare*. At colongitude 82° faint whitish streams, of brightness 7, begin to cover the rocky face. These have further brightened by 90°, but by 103° have again largely disappeared. The formation has been under observation for so short a period, however, that this description should be looked on merely as an indication of what may be expected rather than as a finished report of what generally occurs.

Turning now to quite a different type of formation, we find scattered over the moon's surface, but specially in the equatorial regions, a series of small craterlets whose interior walls under all illuminations are of dazzling brilliancy. The floors of the smaller ones are also bright. One of the best known of these is Mösting *A*, some 5 miles in diameter, 3,000 feet deep, and situated in longitude 5°, latitude −3°. On January 27, 1915, at colongitude 56.3°, the shadow still showed within the crater but had entirely cleared the center of the floor, which appeared of a uniform brilliant white without detail. On March 19, 1913, 61.0°, a minute black dot of less than half a mile in diameter was detected at the center. It was also observed February 18, 1913, 66.0°. On January 28, 1915, 70.1°, the dot was clearly seen, was about a mile in diameter, and was of the same darkness as the region surrounding the crater. Accompanying the dot, and reaching from it toward the north, three-quarters of the way up to the rim, was a faint dark band 1 mile in breadth. This was observed March 20, 1913, 71.4°, though of slightly greater breadth and much greater density, and also on January 29, 1915, 82.0°. No change was detected March 21, 1913, 85.7°, but February 2, 1915, 132.5°, the shadow had appeared on the eastern side, and the canal [or band] had almost completely faded away. The next night both the canal [or band] and central dot had vanished, and the floor was a uniform white. The crater is clear of shadow for about 70° of colongitude. Herschel *c* and Lalande *D* exhibit similar peculiarities. In *c* the canal extends toward the west, and in *D* northwest. In all cases as the sun rises higher and higher upon them the snow melts, and after midday forms again.

We will turn now to another type of white spot, the only one which has been investigated micrometrically. We refer here to Linné. An account of it is given in the Harvard Annals, **61**, 100, where measures by the writer in 1897, 8, by Prof. Barnard in 1902, 4, and by Prof. Wirtz in 1904, 6 are compared. All three agree in showing a marked diminution in size as the lunation progresses, up to a certain point, and after that an increase. According to the first two, the minimum size is reached at about 12° past midday for Linné, and the diameter about sunset is slightly less than about sunrise. Prof. Wirtz, on the other hand, finds the minimum size occurs 12° before midday, and the diameter at sunset to be much larger than at sunrise, which would indicate a certain melting during the lunar night. All three agree, however, that the diameter fluctuates through a range of about 3″. Irregular changes in the shape of the spot and its surroundings were noticed by all three observers.

Thus, Prof. Barnard, on September 1, 1903, detected a small bright point preceding the spot, 5.4″ from its center. On February 12, 1905, Prof. Wirtz saw two irregular, extremely delicate, bright offshoots on the otherwise well-rounded spot; the next day these offshoots had disappeared, leaving the spot slightly elongated. Other observers besides the writer have found the size of the spot to increase slightly at the time of a lunar eclipse, so that a certain amount of literature upon the subject has already accumulated.

Mr. J. G. Burgess, of the British Astronomical Association, has recently called my attention to a spot situated some 12 miles north of Littrow *B*, in longitude 330°, latitude +22°, which is of the Linné type, and according to his description should be of greater interest than Linné itself at the present time, since it contains considerable fine detail close to the crater. His statements are in part confirmed by the writer's Photographic Atlas.[4] Mr. Burgess proposes soon to publish an account of his observations, the results of which in general resemble those made upon Linné. The writer examined the region February 2, 1915, at 132.8° and found covering it at that time a very thin white veil whose density was 0.2 of a unit of brightness. This veil was 6 miles in diameter. The next night it had entirely disappeared. This spot should be of particular interest at the time of a lunar eclipse, since the detail near the crater should make drawings available, thus avoiding some of the subjective systematic errors incident to micrometric measurements.

Conclusion.

It has been the writer's object in the present article to show, not that periodic changes occur in the brighter regions of the lunar surface, for that was known before, notably in the case of the region surrounding Tycho, but to show in just what these changes consist. For this purpose he has selected small bright spots lying in regions showing sharply defined minute detail, in order that the minute changes everywhere occurring upon the moon could be more clearly defined. In order to make the study general, he has also selected the three different types of surface—elevations, depressions, and level areas.

The point of first interest, perhaps, in this investigation is to find when the spots reach their minimum size. Within the craters the dark areas appear and disappear at about the same interval before and after midday, which therefore seems to be the time when the snow presents the smallest area. In the case of Linné, Prof. Barnard and the writer agreed that the minimum occurred one terrestrial day after lunar midday. Since the deviations of their observations from their respective curves were appreciably smaller than those of Prof. Wirtz, doubtless due to better atmospheric conditions in America, and since a minimum occurring after noon seems more probable than one occurring before it, the writer has adopted that view. It would certainly be of interest to prepare a series of drawings of the craterlet near Littrow *B* and determine when its minimum occurs. In the case of Linné and apparently also of Littrow, the white spot is invisible both at sunrise and sunset. Just why this should be so is not very clear, but it would seem to indicate that the moisture can only escape from the vent about midday, and that toward sunset it all evaporates. Toward noon the evaporation occurs before it can get far from the vent; hence the spot is smaller, although brighter at that time than earlier or later.

In the case of the mountains, Pico, Pico *B*, and Straight Range, most of the white spots grow smaller the longer the sun shines on them. Those on the west side of the mountains, toward the rising sun, are of full brightness when the sun first strikes them. Those on the east do not deposit until the sun has been shining on the region for a day or two. It appears as if the ground some little way beneath the surface must be heated up before the moisture can escape. The spots on the western side, on the other hand, must be formed very shortly after the sun sets on them, but while it is still daylight in the surrounding region, for it is clear that nothing can deposit during the night, or both sides of the mountain would be brilliant when the sun first reached them. Pico *c* was seen in January, 1915, distinctly to grow in size and spread over the dark surface of the mountain between colongitudes 9.0° and 16.6°. It then decreased in area until 32.9°, figure 2, after which it increased a second time in size until 55.9°, figure 3, and then rapidly diminished until 68.1°. It had not changed at 81.8°, figure 4, but when the region was next observed at 132.2° the spot was found to have disappeared.

The writer has sometimes been asked, "*What reason is there to believe that there is ice upon the moon?*" The answer is: "For the same reason that we believe there is ice upon Mars, because the phenomena observed can be more readily explained that way than any other." Whether the ice is deposited upon the surface or floats as inute crystals just above it in the form of surface clouds o fog, is not yet clear, but it is believed it occurs in both rms. Where the boundaries are sharply defined it lies pon the surface. Where the boundaries are indistinct and hazy—as, for instance, in the case of Linné—it is still uncertain. In the case of the bright rays surrounding Tycho, it is thought the ice crystals are supported in the lunar atmosphere like those terrestrial cirrus clouds to which we give the name "mare's tails."

[4] Annals, Harvard College observatory, v. 51.

AGRICULTURAL METEOROLOGY.[1]

J. WARREN SMITH, Professor of Meteorology.

[Dated: Weather Bureau, Columbus, Ohio, 1915.]

(Author's résumé.)

In this paper agricultural meteorology is defined as meteorology conducted in the interest of agriculture. A part of agricultural meteorology is agricultural climatology, which shows the effect of climate upon the geographical distribution of vegetation and the adjustment of farm activities.

[1] Read before Section IIB, Second Pan-American Scientific Congress, Washington, Dec. 28, 1915. Will appear in full in the special publication issued by the Ohio Academy of Sciences on the occasion of its twenty-fifth anniversary.